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A GRAPHICAL USER INTERFACE (GUI) FOR ASSESSING THE SUSTAINABILITY LEVEL OF MANUFACTURED PRODUCTS: AN AUTOMOTIVE COMPONENT CASE STUDY

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Abstract
The capability to manufacture sustainable products has become an important requirement for various manufacturing companies. Subsequently, the ability to assess the sustainability of a manufactured product within any organization would be an important step. Towards this end, different mathematical product assessment methodologies were proposed by researchers but they are deficient in terms of the complexity of the mathematical approaches. Consequently, a GUI was developed to alleviate these difficulties. An automotive component was selected as a case study for demonstrating the use of the GUI. Firstly, seven sub elements were selected, of which, two sub elements were categorized in the environment sustainability element, four were contained in the economic sustainability element and one was grouped in the social sustainability element. Then, Fuzzy Logic (FL) procedure was used for assessing the data and obtaining the sub elements' scores. Finally, the total sustainability index was calculated. The developed GUIs are useful tools in facilitating the process of assessing sustainability.

Keywords: Sustainable product, Graphical User Interface (GUI), fuzzy logic, sustainable development

Abstrak
Keupayaan untuk membuat barangan yang lestari telah menjadi satu keperluan yang penting untuk pelbagai syarikat pembuatan. Seterusnya, kebolehan untuk menilai kelastarian sesebuah barangan pembuatan yang dibuat di mana-mana organisasi merupakan satu langkah yang penting. Selaras dengan itu, pelbagai kaedah penilaian barangan secara matematik telah dicadangkan oleh para penyelidik akan tetapi mereka mempunyai kekurangan dari segi kerumitan pendekatan matematik tadi. Oleh yang demikian, satu GUI telah dibangunkan untuk mengurangkan kerumitan yang dialami. Sebuah komponen automotif telah dipilih sebagai kajian kes untuk menunjukkan penggunaan GUI. Pada peringkat awal, tujuh sub unsur telah dipilih, di mana, dua sub unsur dikategorikan dalam unsur kelestarian alam sekitar, empat terkandung dalam unsur kelasterian ekonomik dan satu dikumpulkan dalam unsur kelasterian sosial. Kemudian, tatacara logik kabur (Fuzzy Logic – FL) digunakan untuk menilai data dan memperoleh mata nilaian sub unsur. Akhir sekali, indek kelasterian jumlah dikira. GUI yang dibangunkan merupakan alat penting untuk menyelaras proses penilaian kelasterian.

Katakunci: Barangan lestari, Antaramuka Pengguna Grafik (Graphical User Interface - GUI), logik kabur, pembangunan lestari

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1. INTRODUCTION

All levels of decision making uses the concept of sustainable development (SD) in a widely manner. Environment, society and economy are three core aspects of SD. SD is considered in different study areas such as urban sustainability [1], sustainable energy [2], sustainable society [3] and sustainable agriculture [4]. Due to the numerous energy and material input and output streams involved in manufacturing processes, the need for sustainable manufacturing is well recognized among researchers and manufacturers. According to the National Council for Advanced Manufacturing [5], sustainable manufacturing includes manufacturing of sustainable products and the sustainable manufacturing of all products. Consequently, the first part of this definition includes manufacturing of renewable energy, energy efficiency, green building, and other green and social equity-related products and the second part focuses on the sustainable manufacturing of all products with consideration of the full life cycle stages of the product manufactured. In order to achieve sustainable manufacturing, sustainable products need to be manufactured. Consequently, these manufactured products should be assessed towards their impacts on three roots of SD.

Different methodologies were proposed by many researchers for assessing the sustainability of products [6-10]. Among all of these methodologies, the same deficiency was identified which is the use of complex mathematical approaches for sustainability assessment. In this paper, MATLAB software was utilized to develop and program a Graphical User Interface (GUI) which embedded the mathematical approaches under the interface layer by means of programming codes thereby making the assessment easier for the sustainability assessor staff within any organization. Hemdi *et al.* [10] developed an assessment methodology based on fuzzy logic theory which was used as a basis for product sustainability assessment methodology in this research work.

1.1 Graphical user interface (GUI)

In this phase of study, a GUI was developed and programmed using MATLAB software in order to be used for any company who want to assess the sustainability level of their products. This GUI is flexible and can be programmed for any company or user in order to meet their needs, selected elements and sub elements. In this project, an initial prototype of this GUI is presented for illustrating the way in which it could be applicable. Basically, there is no similar published study in the area of sustainable product or process design assessment software. Just recently, Hai *et al.* [11] developed software for sustainability assessment in the field of rural and town sustainability. Visual Basic software is used to develop a software package based on Delphi, analytic hierarchy, normalization and combination processes. But this software is just designed for assessment of environment and health sustainability and also is not applicable for assessing of all three dimension of sustainability even in the same field. Before that, Chi [12] developed computer simulation models for sustainability.

2. METHODOLOGY

The developed GUI is based on MATLAB platform and uses fuzzy logic process to assess the total sustainability index. The GUI facilitates the sustainability assessment of a particular product in a minimum time. In order to use this GUI, there is no need for the user to have knowledge about fuzzy process or any other kinds of algorithms. So, this can be considered as the most important advantages of the developed GUI. Fig. 1 shows the general procedure of using this GUI. In addition, the main menu of the GUI is shown in Fig.2 in which user can select which sustainability element needs to be computed.

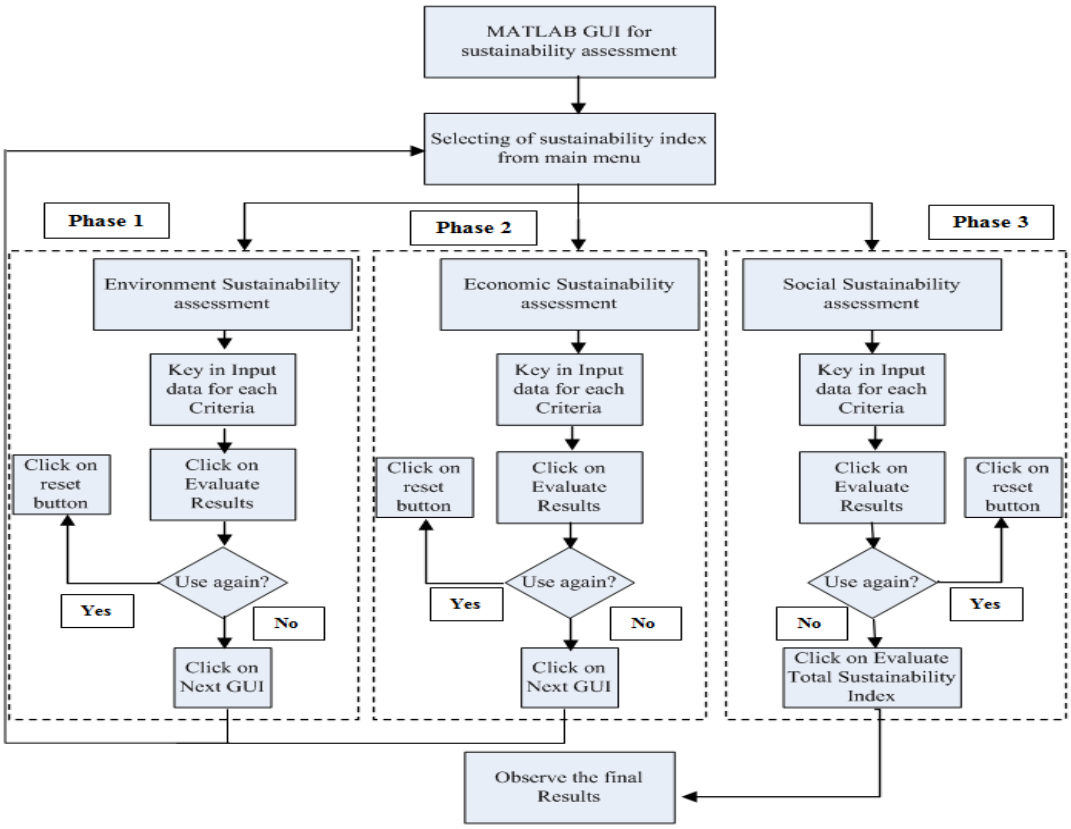

Fig. 1. GUI usage methodology

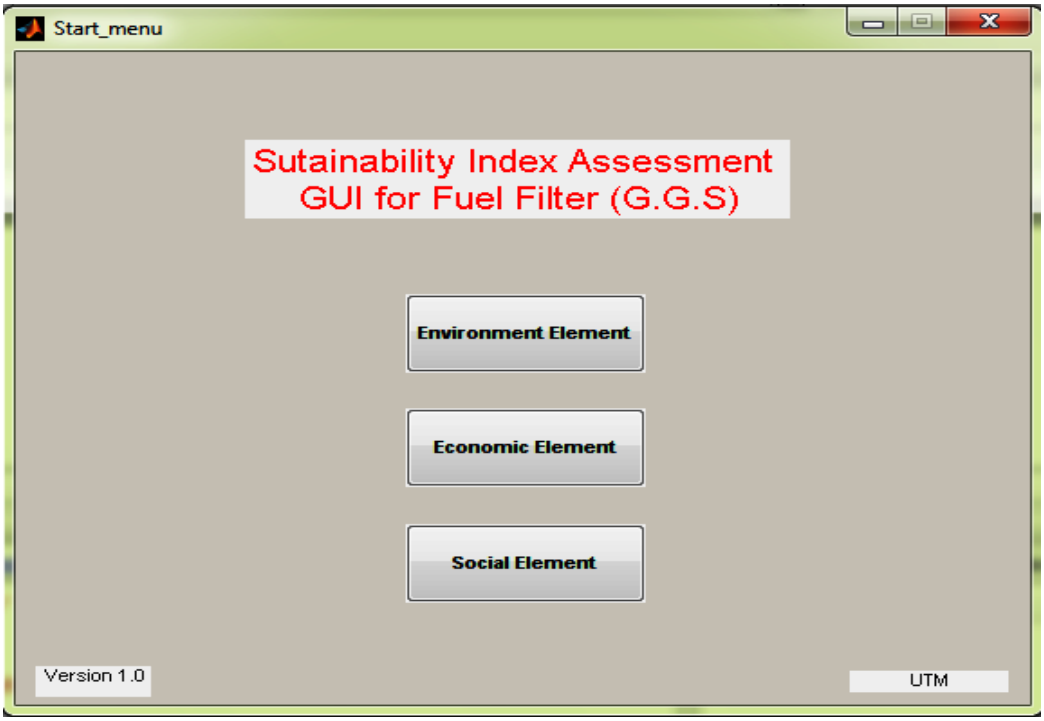

Fig. 2. Main menu

3. RESULTS AND DISCUSSTION

In order to customize this GUI, a case study was selected. This case study was conducted in an automotive components manufacturing company (hereafter referred to as GGS). Fuel filter was selected as the appropriate product to be assessed. This decision was taken based on the consultation with the manager and executives of GGS. The reasons for the selection of fuel filter were based on high production rate, high customers' demand and availability of required data for this product. The boundary of analysis for this case study is from the "Cradle to Gate" which covers two stages of the product life cycle, from raw material extraction until the end of manufacturing stage. Consequently, this case study involves a partial assessment which is due to the lack of all appropriate data which would be needed for the complete assessment.

After selecting the product, project was followed by identifying the sub elements and influencing factors which was done based on various studies, reviewing the literature [13-17] and discussion with the decision makers of GGS. In this case study, owner of the company, chief executive officer, general manager and a system manager were selected as the expert decision makers. Experts' opinions were used for validating the selected sub elements and influencing factors. Based on selected sub elements and influencing factors, GUIs were customized and fuzzy codes were written using MATLAB programming language. The prototypes of constructed GUIs are shown in Figs. 3-5. A user can get benefit from these GUIs based on the instruction which is illustrated in Fig. 1.

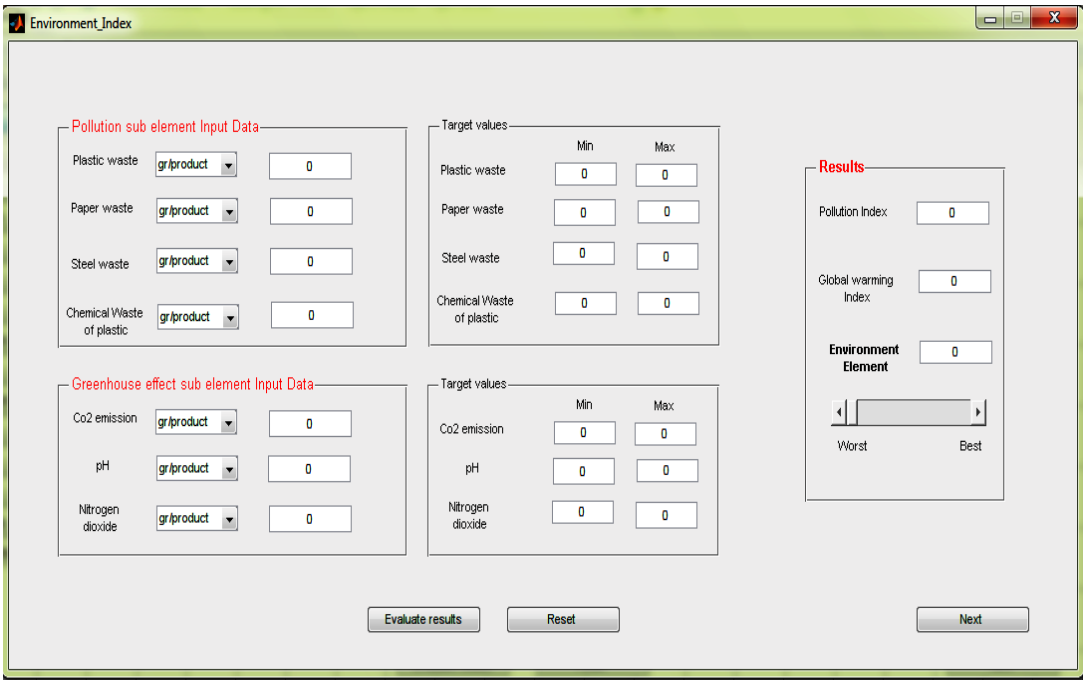

Fig. 3. Environment element GUI

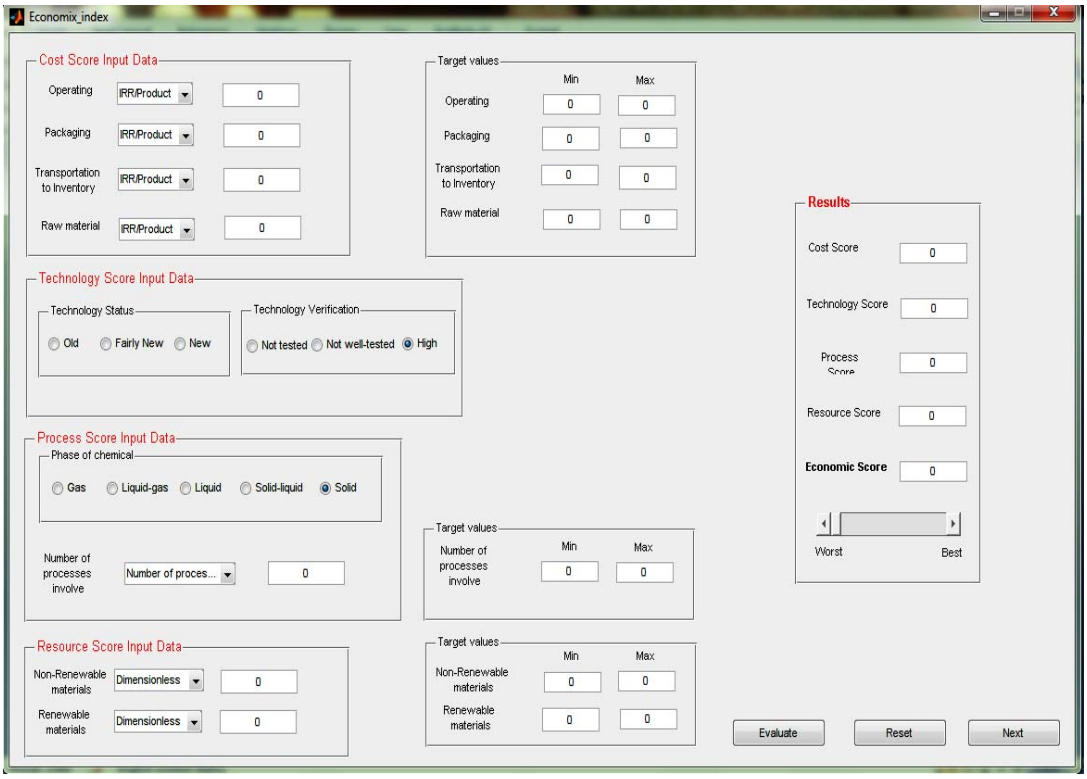

Fig. 4. Economic element GUI

Fig. 5. Social element GUI

After continuing the assessment based on the procedure previously illustrated in Fig. 1, the final sustainability index can be calculated by clicking on "Evaluate Total Sustainability Index". All calculated results for this case study are presented in Tables 1-4.

Table 1. Scores obtained for environmental sustainability sub elements

Influencing factor	Sub element	Overall score
CO_2 emission pH NO_2	Greenhouse effect	0.546
Plastic waste Steel waste Paper waste Chemical waste of plastic	Pollution	0.412

Table 2. Scores obtained for economic sustainability sub elements

Influencing factor	Sub element	Overall score
Technology status Technology verification	Technology	0.92
Operating Packaging Transportation to inventory Raw material	Cost	0.514
Number of processes involved Phase of chemical	Process	0.727
Non-renewable materials Renewable materials	Resource	0.297

Table 3. Scores obtained for social sustainability sub element

Influencing factor	Sub element	Overall score
Mercury Particles (PM10) Safety risk Sulfur dioxide	Social Performance	0.552

Table 4. Calculated sustainability elements scores and total sustainability index

Element	Element score	Total sustainability index
Environmental sustainability	0.479	
Economic sustainability	0.6145	0.5485
Social sustainability	0.552	

4. CONCLUSION

As it was shown, the proposed GUI based on MATLAB software can simply perform the assessment. Moreover, all of its calculation are embedded under the GUI layer and done with codes and callbacks. So, there is no need for the user to know anything about mathematical approaches such as fuzzy logic. Besides that, another feature of this GUI is “easy to use” capability which is an important issue in developing any GUI. The major contribution of this research activity is developing a GUI which can be easily applied using a Microsoft platform

and MATLAB Software. In other words, it provides a computer-based tool to support decision making. Also, it has a high degree of flexibility. For future works, this initial GUI can be enlarged for all the products produced in the company. Also, it can be expanded as a database system within any company for sustainability assessment.

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